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ABRASIVE MACHINING OF MINOR COMPONENTS FOR CANNON MANUFACTURING

JOHN RODD

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US ARMY ARMAMENT COMMAND

BENET WEAPONS LABORATORY
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Many developments have contributed to the increased productivity of grinding in the past few years. The one that has attracted the most attention is "abrasive machining". The term "abrasive machining" has been expressed in many ways. It is generally used to denote stock removal operations that are more economically performed by abrasive grinding methods than the more conventional means of turning or milling. The two biggest fields for abrasive machining are the production of flat surfaces and form grinding from the solid. In this program we are con-

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20.

-cerned with the latter; grinding various complex external shapes from the solid forging, bar stock or hollow cylindrical items.

Abrasive machining has been used in recent years to denote those grinding operations in which metal removal rate, surface finish or accuracy, is the main consideration. It includes all the operations where cost is a major factor in determining whether to grind or to machine with carbide or high speed steel cutters.

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Statement of the Problem: The primary purpose of this project was to develop major capital equipment and techniques for the manufacture by abrasive machining of minor cannon components and to develop a process for producing metallurgical test specimens from a wide variety of test materials by abrasive machining.

Background and Introduction: Abrasive machining was investigated several years ago and at that time it was determined that little progress had been made in increasing the efficiency of the abrasive grain as a cutting media. Considerable research had been performed which indicated a much more effective metal removal potential was possible but no practical technique was developed to make this potential available for production use. Abrasive machining was a misnomer five years ago when equipment with greater power and abrasive exposure increased metal removal rates, but only in proportion to the ratios of smaller machines. Higher horsepower drive systems along with wheel loading and grain composition were only a few factors which had to be resolved before the term could be genuinely applied.

Bendix Corporation, Automation and Measurement Division, had perfected experimental equipment and techniques that showed abrasive machining to be a realistic production tool. Metal removal rates of the experimental machine exceeded those of conventional cutting tools. Tool life, operating costs, capital investment, flexibility, and reduced labor requirements were all to benefit by the use of suitable application of abrasive machining. A survey of minor ordnance items revealed that the geometry of several cannon components fit the parameters of abrasive machining ideally. Therefore, it was felt that a comprehensive program would produce exceptional results and reflect substantial monetary gains.

Several components were selected for experimental abrasive machining on modified converted factory equipment, to evaluate performance versus current practices. The success of this experimental application led to the development of engineering specifications for the design and construction of highly specialized capital equipment. The work performed encompassed the following primary subjects of investigation: engineering design of complex capital equipment, techniques, production, tooling, speeds, feeds, and cost analysis.

It is the objective of this report to inform personnel responsible for the manufacture of cannon parts of the advantages to be gained by the use of abrasive machining. This program is designed primarily to show the cost reduction that can be achieved while at the same time improving the quality of the parts. Completing a part with one plunge of the grinding wheel reduces the number of machining operations and much of the handling of the parts. The benefits to be gained are many fold and justify the amortization of the equipment over a reasonable period of time.

Approach to the Problem: Many developments have contributed to the increased productivity of grinding in the past few years. The one that has attracted the most attention is "abrasive machining". The term "abrasive machining" has been expressed in many ways. It is generally used to denote stock removal operations that are more economically performed by abrasive grinding methods than the more conventional means of turning or milling. The two biggest fields for abrasive machining are the production of flat surfaces and form grinding from the solid. In this program we are concerned with the latter; grinding various complex external shapes from the solid forging, bar stock or hollow cylindrical items.

Abrasive machining has been used in recent years to denote those grinding operations in which metal removal rate, surface finish or accuracy, is the main consideration. It includes all the operations where cost is a major factor in determining whether to grind or to machine with carbide or high speed steel cutters. To compete with other processes, machines used for abrasive machining must employ much higher horsepower wheel drives and must be dynamically stiffer to utilize this power.

To realize the most benefit from high speed grinding and abrasive machining, the entire system should be utilized. This includes special grinding wheels that have adequate strength to withstand the increased stresses at the elevated wheel speeds, machines that have sufficient dynamic rigidity, grinding fluids that are properly selected and effectively applied, and a truing medium that offers efficient wheel dressing.

It is worth noting that form grinding can remove stock very rapidly and yet cause only an extremely small amount of wheel wear if the proper operating conditions have been selected. Form grinding is able not only to remove stock rapidly, but also to produce accurate parts more reasonably.

There are three generally accepted ways to produce the contour on a grinding wheel for form grinding. One employs a single point diamond, controlled by a template device. This method is slow and dulls the wheel as a diamond will cut off all the sharp grit as it traverses across the wheel. Another uses diamond roll dressing or CDP (Cemented Diamond Particles). In this method, a small form roll, covered with diamond particles of the same cross section as the work piece, is driven against the rotation of the wheel, cutting the inverse form onto the grinding wheel. This method of dressing is fast, but also dulls the wheel, making it necessary to dress the wheel more often.

The latest and most successful method is the crush dressing process. A hardened roll having the same cross section as the work piece is forced to run with the wheel under pressure at a slow R.P.M. This imparts the inverse form of the roll onto the wheel. Rolls are about 1/5 the diameter of the grinding wheel. They can be made of H.S.S.*, carbide or boron-carbide, depending upon the form and the roll life desired.

*High Speed Steel

There are quite a few advantages of crush dressing over the other conventional methods. In the crushing process, the roll does not do any cutting, but breaks down the bond of the wheel, allows the loose grit and bond to be washed away and leaves the sharp edges and points of the remaining grit exposed to do the grinding. The wheels are sharper and consequently cut faster, cooler and longer between dressings. Crushing leaves a more open structure or voids to carry lubricant to the cutting zone. This reduces dulling of the wheel and surface heat in the part.

Carbide rolls, which are recommended for this project,are much more economical than diamond rolls. The cost ratio is approximately 3:1. Work piece dimensions and tolerances can be changed by regrinding the crush roll. It is usually very difficult and not practical to make changes on a diamond roll.

Whether or not a grinding wheel dulls in use, it may become loaded with particles of the material being ground. This can lead to excessive heat generation, poor finish and inaccurate parts. Wheels are dressed not only to expose sharp abrasive grains, but also to get rid of loading. When loading occurs in the absence of grain dulling, it is advantageous to be able to eliminate it by some means other than dressing, which results in some wheel loss. Industry has developed a device for doing this - the jet wheel cleaner. It oscillates a high pressure (10,000 psi) jet of grinding fluid across the wheel face during grinding. Individual material particles are blasted loose before they become embedded in the wheel. Another benefit of this system is that the grinding fluid is forced into the interstices of the wheel and some of it then is thrown out in the area of grinding contact, just where it is needed to improve the grinding action. This process has resulted in very large improvement in terms of pieces per dressing, production rate and wheel life, and has made it possible to grind forms that could not be produced otherwise. With this in mind, it was decided to conduct experimental tests using the crush technique.

Machine Selection (For Preliminary Experimental Tests)

The three parts selected for this project require the use of two sizes of machines. Part Nos. D-8769051 (175mm and 8" Obturator Shaft - Figure 1) and D-8765800 (105mm Crank - Figure 2) would be machined on an experimental modified multi-form grinder having a capacity of 10" dia. x 24" length of part. Part No. D-8769370 (175mm and 8" Bushing - Figure 3) requires a machine capable of grinding larger diameters. In this case we used a modified experimental Model 187-30 multi-form grinder which has a capacity of 30" dia. x 9" length of parts. The machines selected are versatile, high speed prototype production machines designed for grinding cylindrical parts of intricate and precise profile using the crush process.

Of the three materials which are commonly used for the crusher rolls, high speed steel is the least expensive with the least wear resistance. Boron carbide is the most expensive with many times the wear resistance of high speed steel. High speed steel rolls were selected for this phase because the cost of carbide rolls could not be justified when grinding so few experimental test pieces. However, testing has substantiated that carbide rolls are recommended for production application. They are both reliable and economical and require little or no maintenance.

Coolant System

The coolant system is a critical factor in the abrasive machining process. This includes the cutting fluid, coolant pumps, filtering unit and refrigeration unit. In some cases, special coolant nozzles are required. The most satisfactory coolants for crush grinding are oils. There are several properties desirable in these oils, i.e.:

1. Relatively low viscosity at ambient temperature.

2. Good lubricity.

3. Good heat transfer capacity.

4. Long life.

We found that a coolant flow rate of 2 gallons per minute per horsepower on the wheel spindle is adequate for most jobs when the coolant is properly directed to the cutting zone. Nearly all the grinding horsepower is converted into heat in the grinding process which is concentrated in the cutting zone. This obviously causes high temperature at the interface of the wheel and the work. If the workpiece is slowly rotated, the heat is rapidly conducted into the work and is not easily removed by the grinding fluid. However, if higher work speeds are used, along with reasonable depth of cut per revolution of the work, heat penetration may be reduced by the wheel removing part of the heated work on each subsequent revolution.

Coolants are perhaps the most abused segment of any precision grinding operation in that in many grinding operations the coolants lack cleanliness. The coolant must be clean. This fact dictates the necessity of a filtration system that will remove all particles 25 micron and larger in size. If the coolant is not kept clean, the results are excessive crush roll wear, wheel loading and excessive heat build-up.

It is important to maintain the coolant at room temperature during the grinding operation. This will maintain uniform dimensional performance of the grinding machine and will result in uniform production of parts. Where the heat of grinding is of a magnitude that normal cooling during the filtering cycle will not be maintained at room temperature, refrigeration will be required.

A super jet wheel cleaner, as described previously, is recommended on all abrasive machining operations to prevent wheel loading. The use of a jet wheel cleaner necessitates the use of a mist collector to prevent fogging in the work area.

With all preliminary experimental tests completed, it was felt that sufficient data existed to design capital equipment and peripheral support hardware to complete this project.

Solution to the Problem: A proposed method for manufacturing various components by abrasive techniques was undertaken. In this method a rough forging or casting such as that shown in Figures 1-3 is mounted in the machine and driven against a grinding wheel of sufficient width and diameter, having the inverse form of the component, resulting in a component having the desired configuration as specified on finished drawings. After preliminary experiments had proven the new method practical, consultation and extensive engineering discussions were held concerning total design parameters for the construction of major capital equipment.

Specifications were developed and Watervliet Arsenal advertised a bid for the construction of all necessary equipment. Bendix Company of Dayton, Ohio was the low bidder and was awarded the contract.

Figure 4 is an overall view of the equipment resulting from this effort. To date we have successfully employed this equipment and technique to the manufacture of a variety of ordnance hardware. Illustrations of these items are shown under Figures 1-3 and 5, which is a tensile test specimen.

Production data are shown in Appendix A (Operating and General Set-Up Instruction Section) and Appendix B (Process Data). Cost analysis or cost comparison of each component is included in Appendix C (Cost Analysis Section). The technical data contained within the body of this report has been presented to serve as a guide for the planning and set up of future operations with the abrasive crush grinding equipment. After completion of all preliminary and production testing the established operating procedure was turned over to the concerned operating officials. In order to present additional technical data for presentation to other interested areas, a video tape program illustrating the highlights of this project was completed and is available.

Conclusions:

1. Abrasive Machining is a highly competitive metal removing process with fast stock removal ability.

2. Material waste is reduced because parts can be cast or forged to closer size.

3. Abrasives are not affected by variations of surface quality whereas cutting tools need extra allowances to cut through hard scale or work hardened surface layers.

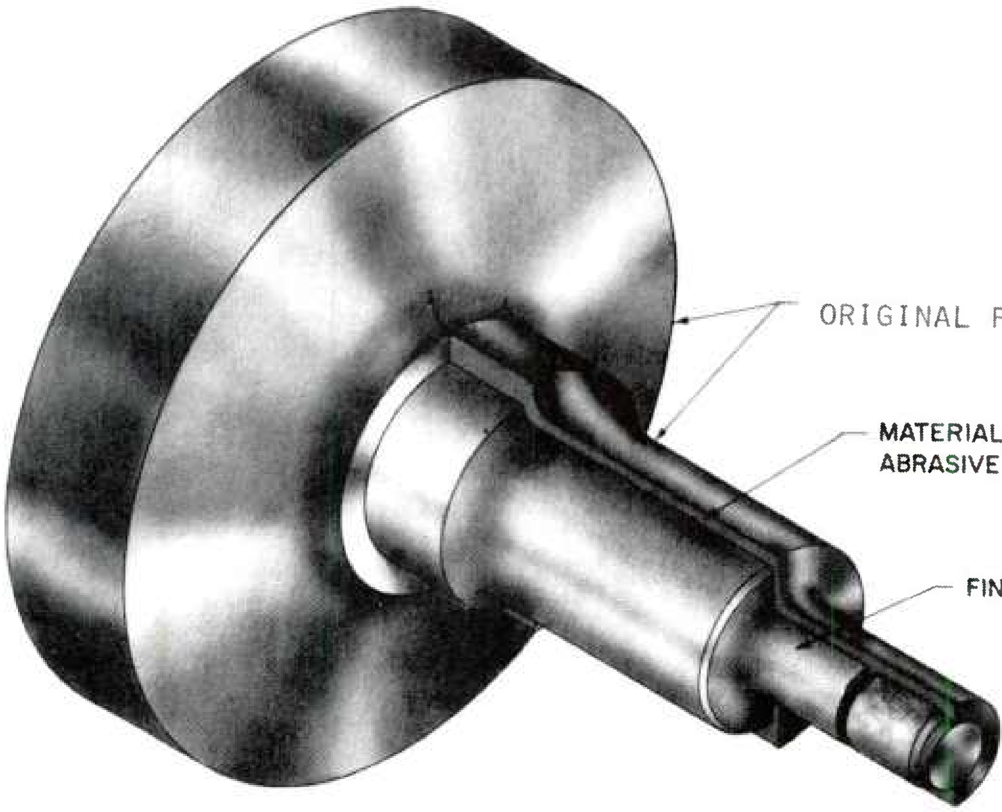
4. Interrupted cuts do not affect abrasive machining.

5. Hardened steels, from R_c 60 up are ground as a matter of course.

6. Tensile test specimens, Figure 5, are made from 1" rough squared stock and were finish ground in four (4.0) minutes. The best comparative process required over one hour of machining time. Tooling costs and maintenance were also commensurately lower where abrasive machining was applied. It is reasonable and realistic to anticipate savings in excess of 85% when this technique and equipment are adopted.

7. In view of the significant reduction in manufacturing costs and the increased production gains resulting from abrasive machining especially in the manufacture of metallurgical test specimens (tensile test items) it is concluded that abrasive machining should be employed over prior machining methods. Abrasive machining should be given primary consideration as a replacement for many current machining operations.

8. The prototype production abrasive machine resulting from this effort has the great advantage of flexibility for the production of a large number of different shapes and diameters, since the machine, crush roll and grinding wheel can be quickly and easily assembled and disassembled. The wheel and crusher roll can be conveniently stored in a tool crib and recalled when that specific part or shape is again required.



STOCK REMOVED BY ABRASIVE MACHINING 17.7 CU. IN. = 5 LBS.

CURRENT MACHINING METHOD:
AVERAGE TIME FLOOR TO FLOOR 3 HOURS = $ 60.00

ABRASIVE MACHINING METHOD:
AVERAGE TIME FLOOR TO FLOOR 16 MINUTES = $ 5.32

SAVINGS: **$ 54.68**

Figure 1. Shaft D8769051 - 175 mm Gun

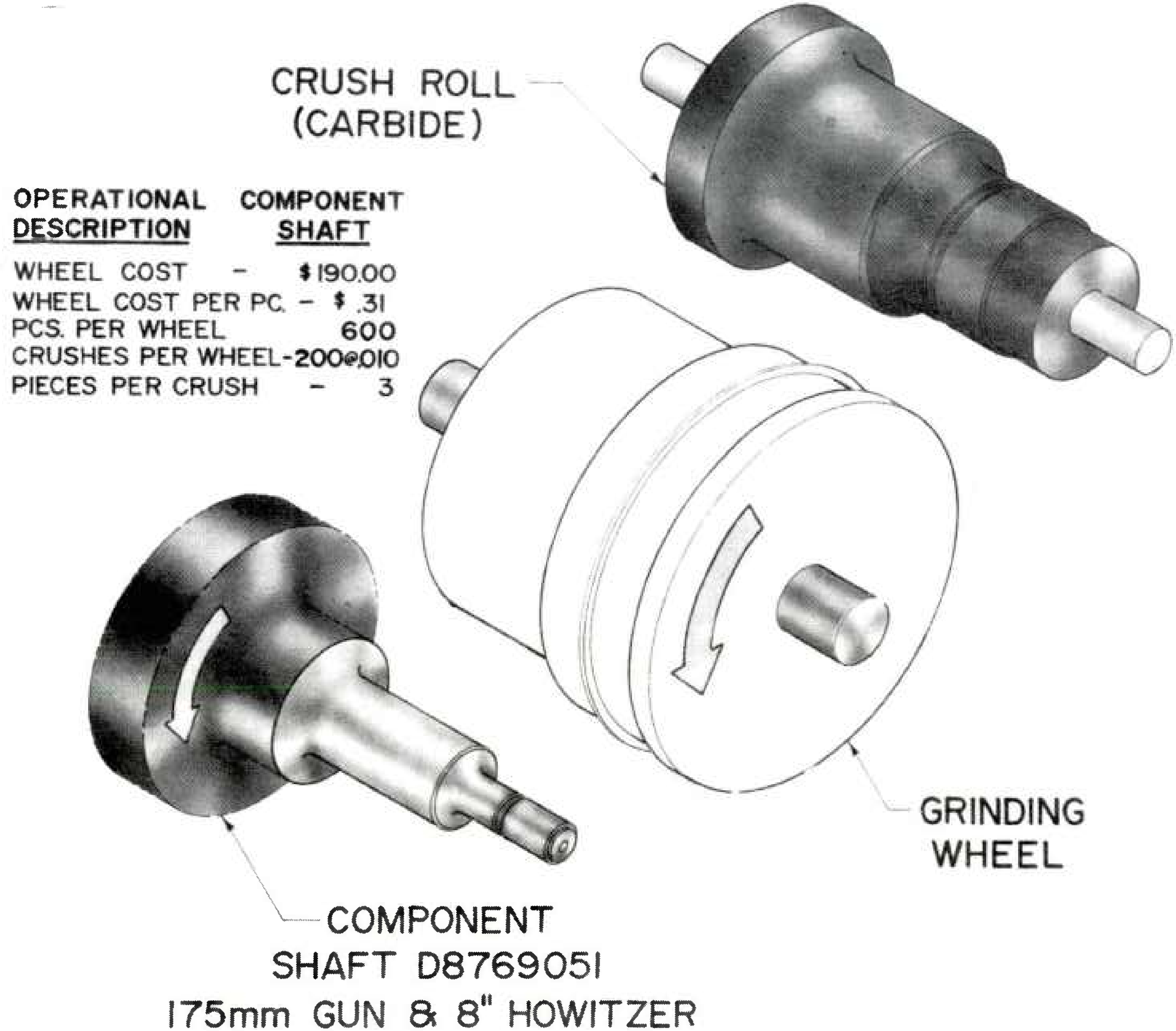
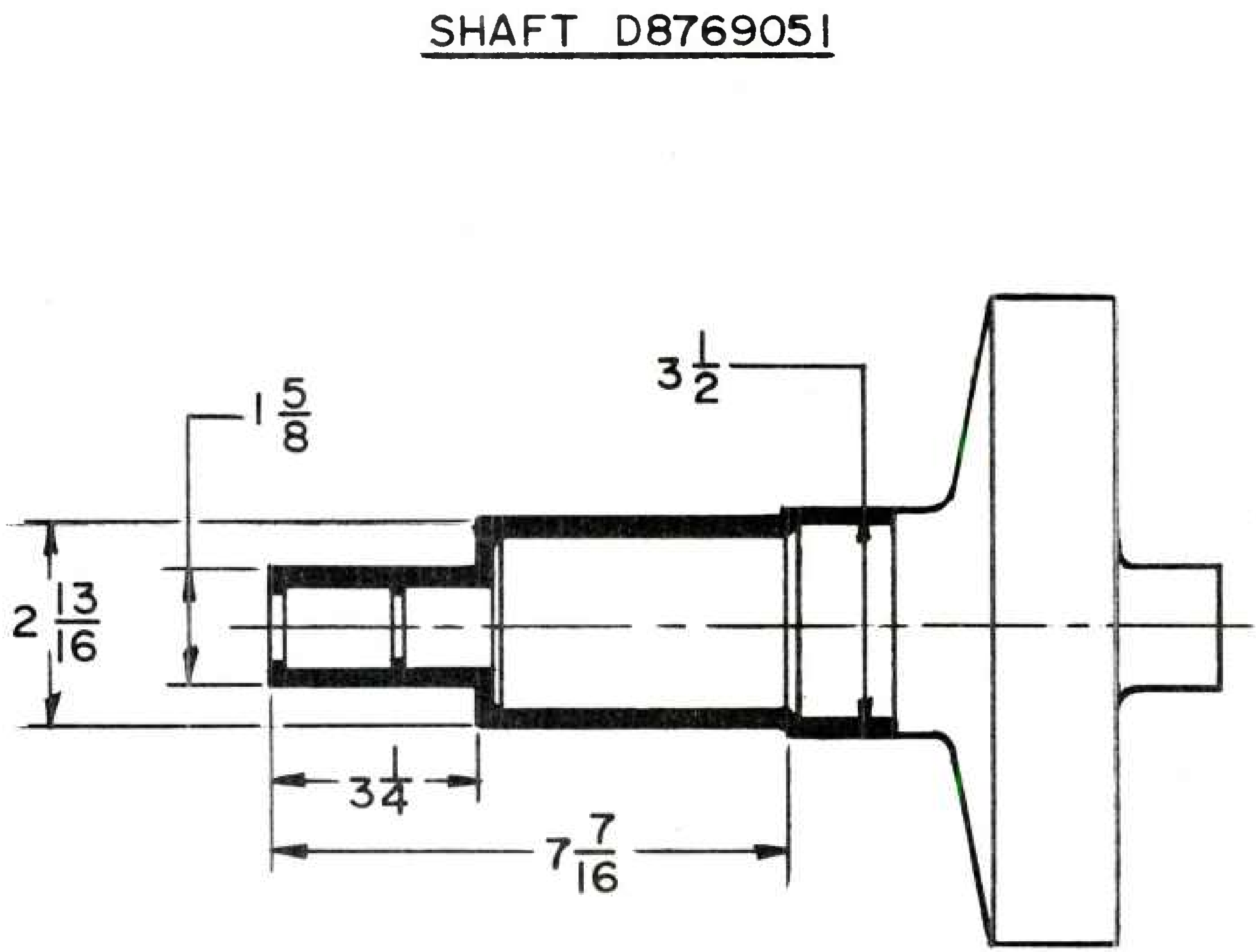


Figure 1(a). External Abrasive Machining Application-Shaft

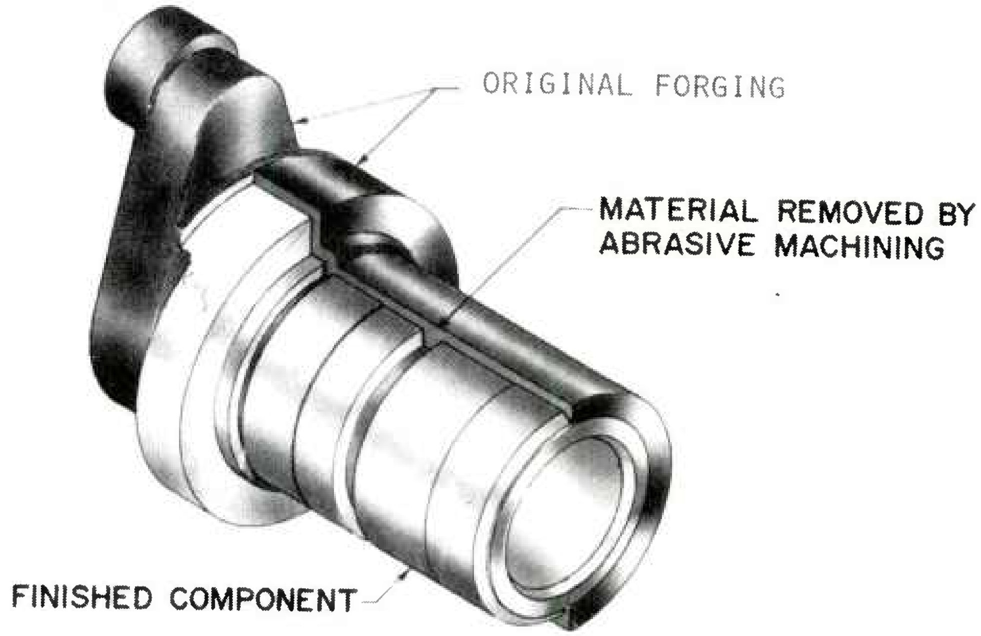


STOCK REMOVED BY ABRASIVE MACHINING

17.7 in^3 = 5 Lbs

AVERAGE GRINDING TIME ____ 16 min EA. PC.

Figure 1(b). Stock Removed by Abrasive Machining-Shaft



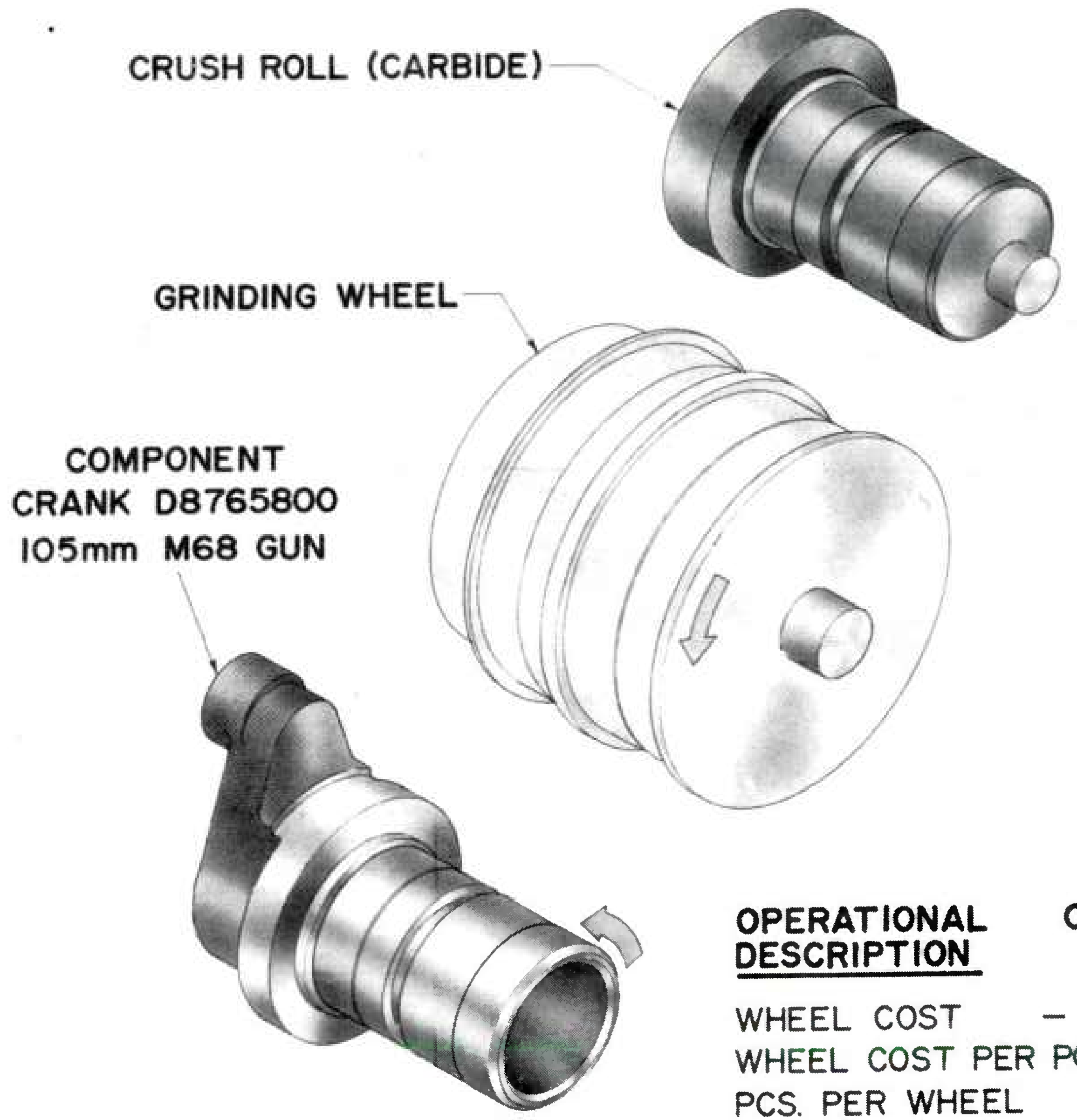
STOCK REMOVED BY ABRASIVE MACHINING 7.3 CU. IN. = 2 LBS.

CURRENT MACHINING METHOD:
AVERAGE TIME FLOOR TO FLOOR 1 HR. 15 MIN. = $25.00

ABRASIVE MACHINING METHOD:
AVERAGE TIME FLOOR TO FLOOR 7 MINUTES = $2.33

SAVINGS $22.67

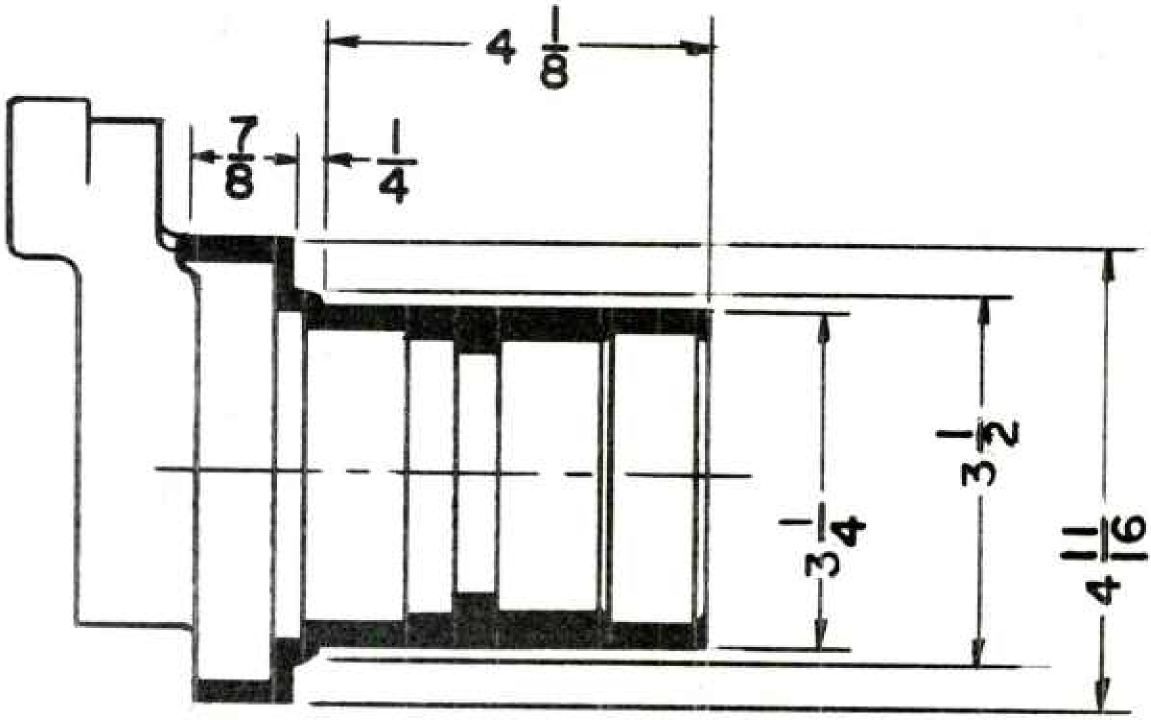
Figure 2. Crank D8765800 - 105 mm M68 Gun



OPERATIONAL DESCRIPTION		COMPONENT CRANK
WHEEL COST	—	$ 245.00
WHEEL COST PER PC.	—	$ .40
PCS. PER WHEEL	—	600
CRUSHES PER WHEEL	—	200
PIECES PER CRUSH	—	3

Figure 2(a). External Abrasive Machining Application-Crank

CRANK D8765800

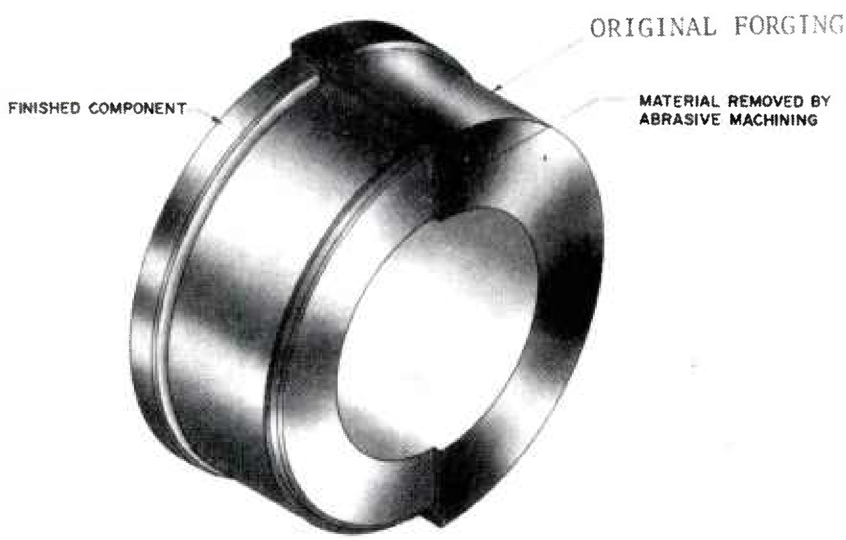


STOCK REMOVED BY ABRASIVE MACHINING

$7.3 in^3 = 2 Lbs$

AVERAGE GRINDING TIME ___ 7 Min EA. PC.

Figure 2(b). Stock Removed by Abrasive Machining-Crank



STOCK REMOVED BY ABRASIVE MACHINING 49.7 CU. IN. = 14 LBS.

CURRENT MACHINING METHOD:
AVERAGE TIME FLOOR TO FLOOR 3 HOURS 15 MINUTES = $65.00

ABRASIVE MACHINING METHOD:
AVERAGE TIME FLOOR TO FLOOR 40 MINUTES = $13.32

SAVINGS: **$51.68**

Figure 3. Bushing D8769370 - 175 mm Gun

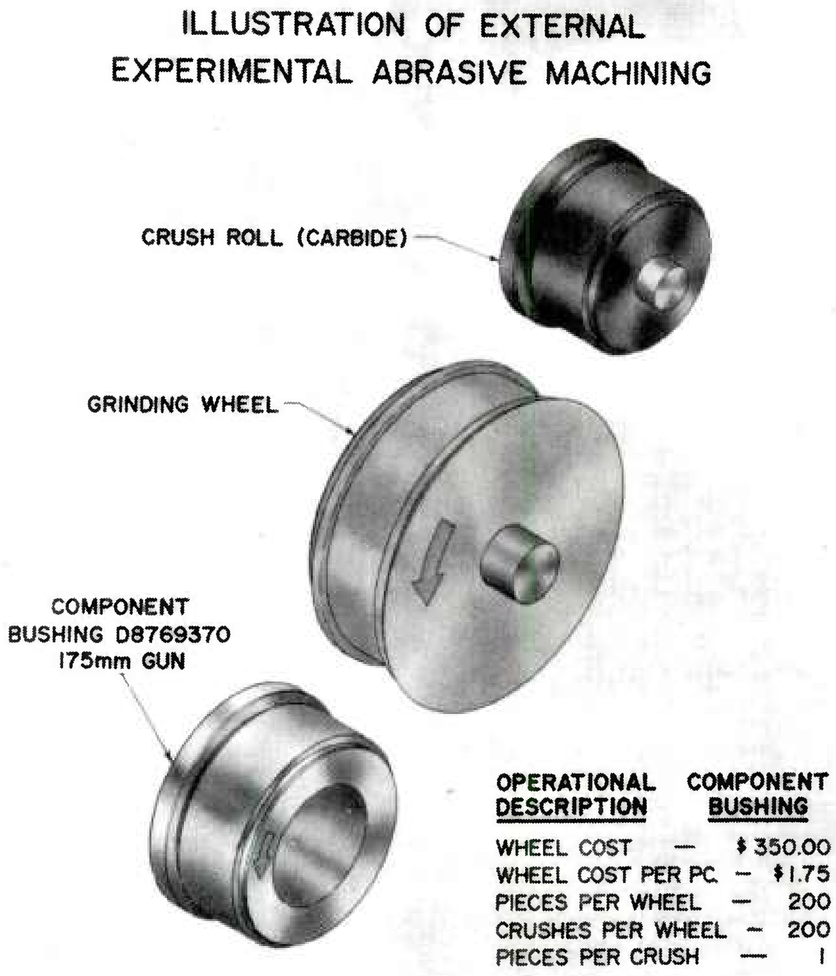
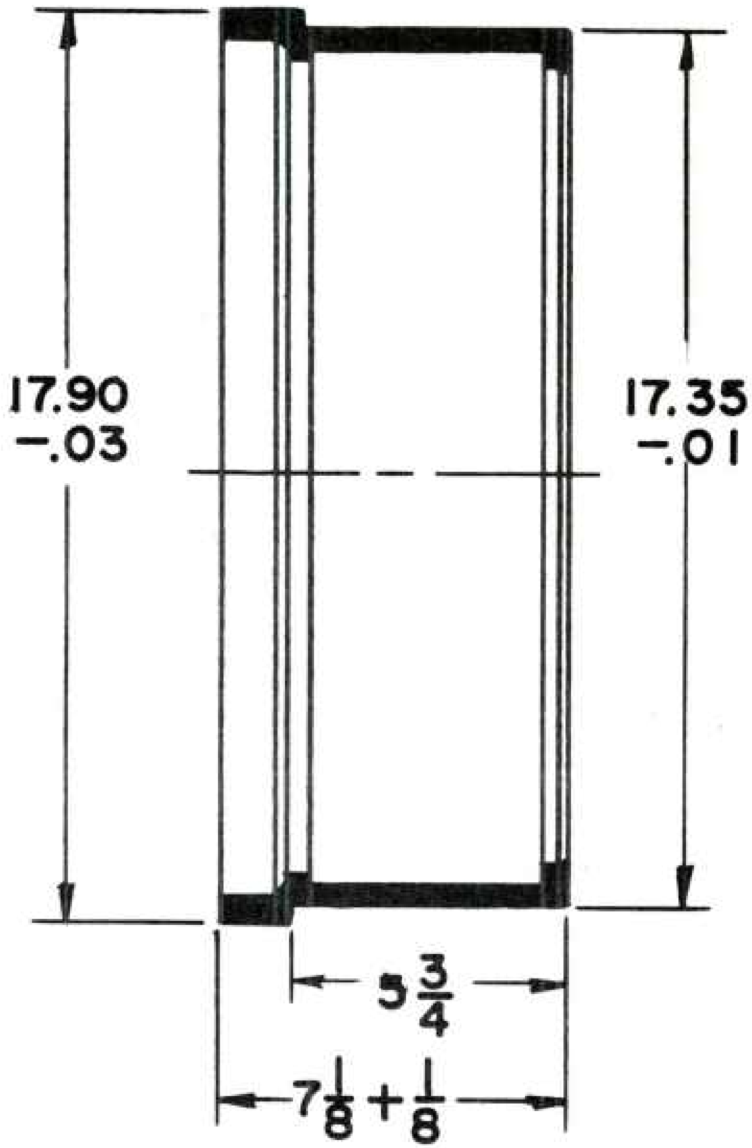


Figure 3(a). External Abrasive Machining Application-Bushing

BUSHING D-8769370



STOCK REMOVED BY ABRASIVE MACHINING

$49.7 \text{ In}^3 = 14.9$ Lbs

AVERAGE GRINDING TIME ____ 40 Min EACH PC.

Figure 3(b). Stock Removed by Abrasive Machining-Bushing

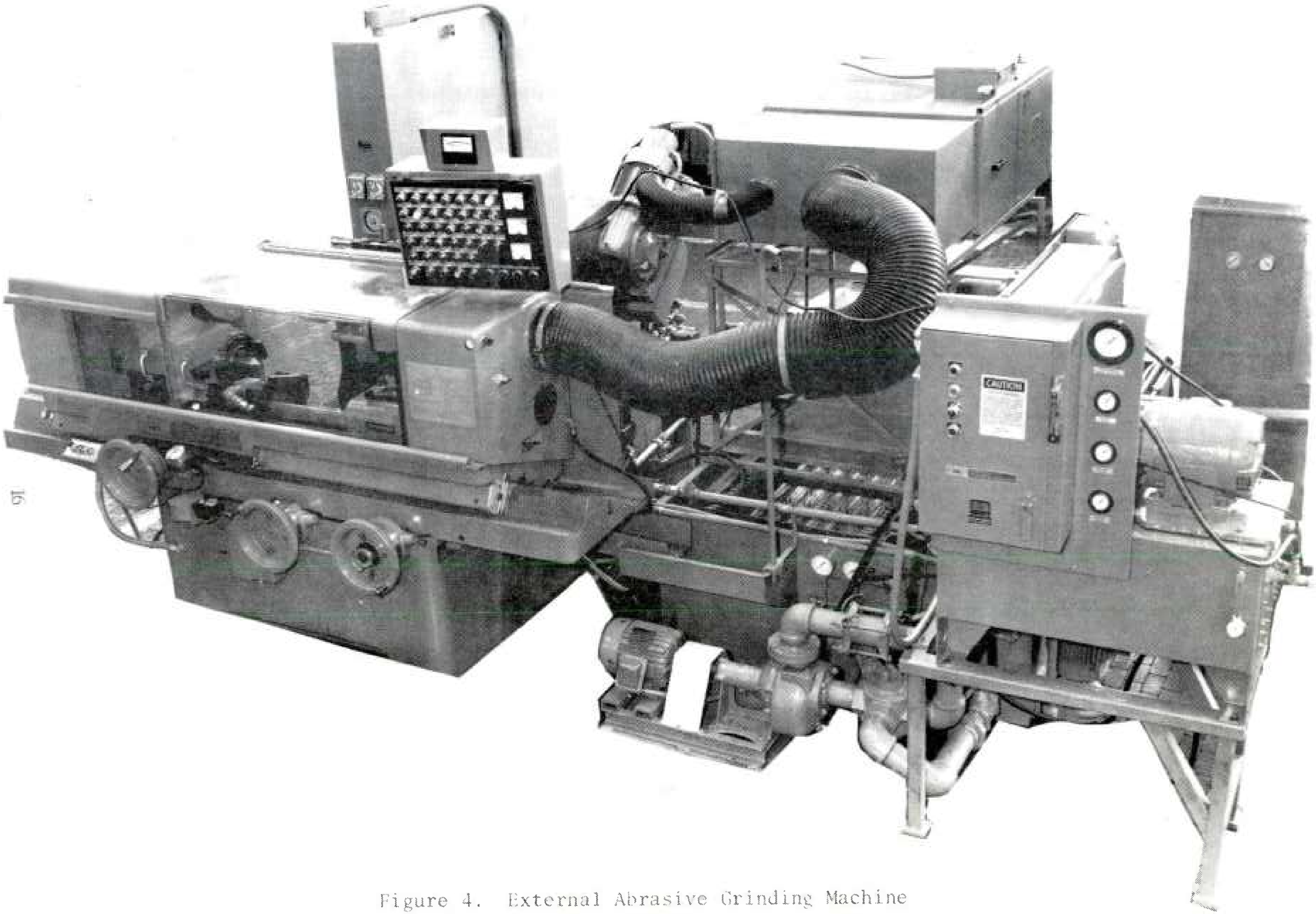


Figure 4. External Abrasive Grinding Machine

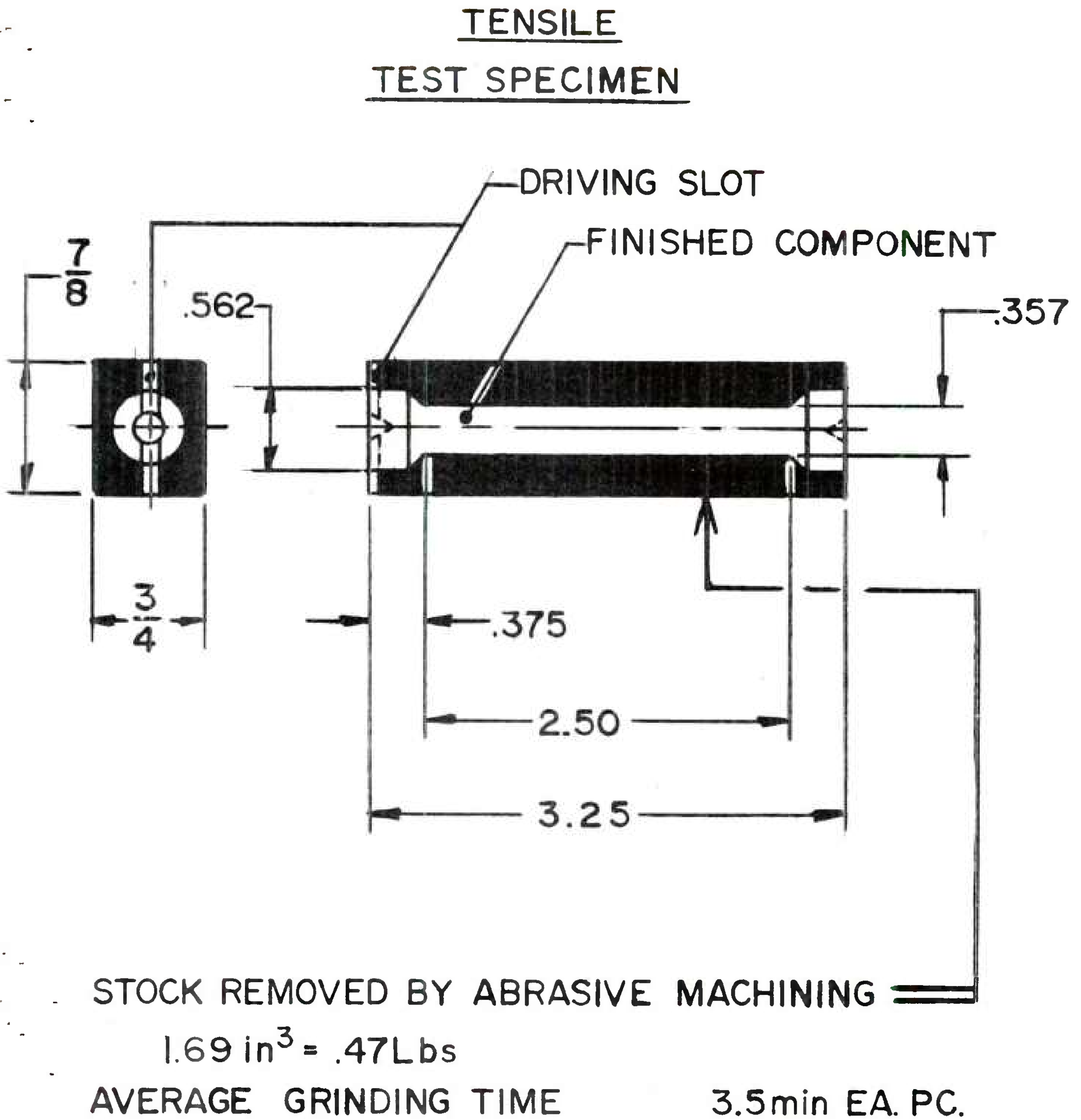


Figure 5. Stock Removed by Abrasive Machining-Test Specimen

APPENDIX A

OPERATING & GENERAL SET-UP

INSTRUCTION SECTION

OPERATING AND GENERAL SET-UP INSTRUCTIONS
FOR THE FOLLOWING COMPONENTS:

1. Shaft, 175 Gun D8769051
2. Crank, 105mm M68 Gun D8765800
3. Bushing, 175mm Gun D8769370

General Description

The Model 187C Crushtrue Grinder incorporates an air bearing worktable to facilitate lateral movement of the workpiece relative to the grinding wheel. The ease of traversing is accomplished by a number of air jets mounted in the underside of the worktable that when pressurized by the main machine pneumatic system levitates the worktable from the fixed machine platen on a thin cushion of air. The "air table" is composed of four basic elements which are illustrated in Figure A1.

1. Platen - A fixed bearing surface which is mounted to the machine base.
2. Worktable - The moveable component in which the air jets are mounted in the underside bearing surface and on which the workhead and tailstock are mounted to the top surface.
3. Traversing Mechanism - The lateral movement is accomplished by the leftmost handwheel on the machine. A Vernac Direct Reading Precision Optical Measuring System is provided for accurate lateral positioning. Instructions on operation of the Vernac readout are provided in a separate manual.
4. Control Station - The air table control station is mounted on the platen to the left of the traversing handwheel. Figure A2 illustrates the control station layout and gives a brief description of the control functions.

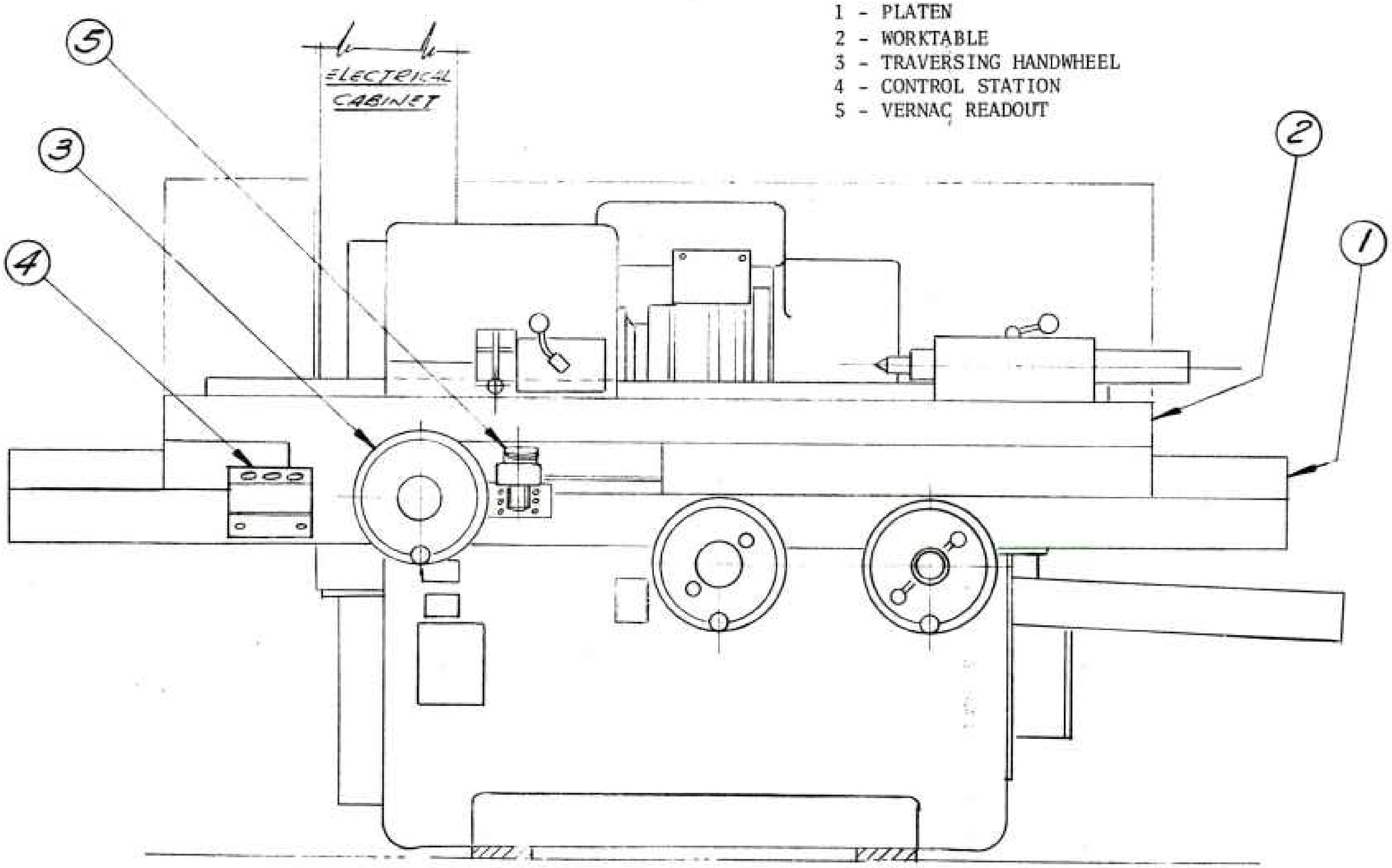
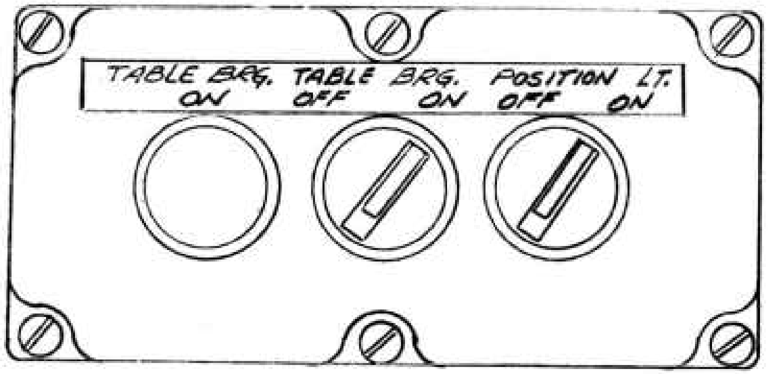


Figure A1. Front View of the Model 187C



ITEM	NAME AND FUNCTION
1.	TABLE BEARING ON LIGHT (RED) INDICATES TABLE BEARING IS ON.
2.	TABLE BEARING OFF-ON SWITCH ACTUATES AIR BEARING TABLE.
3.	POSITIONING LIGHT OFF-ON SWITCH ACTUATES VERNAC DIAL LIGHT.

Figure A2. The Air Bearing Worktable Control Station Layout

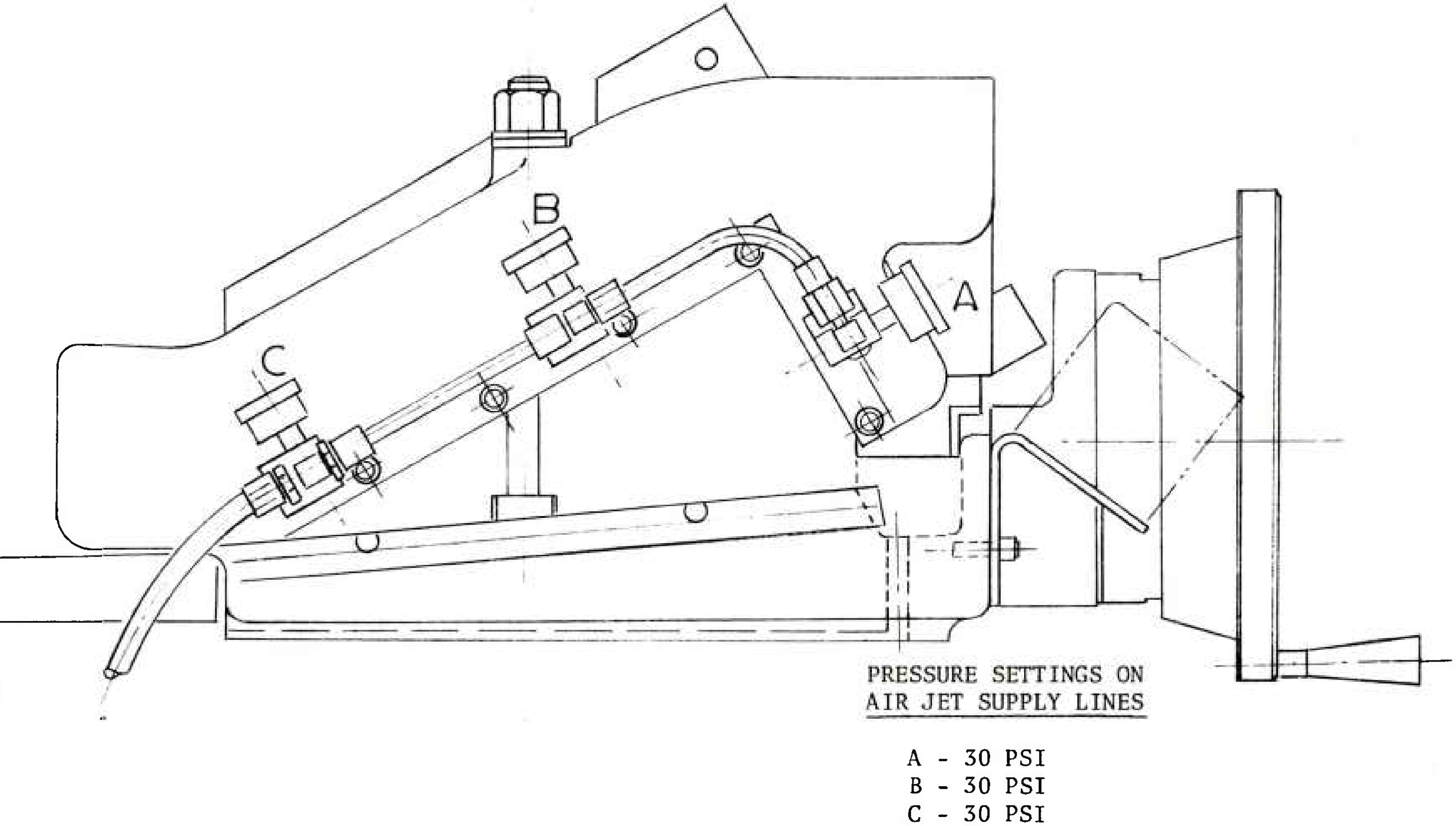


Figure A3. Left Side View of 187C Air Bearing Worktable

Set-Up Procedure

Since the air table operates from the main machine pneumatic system, an air supply of 40 cfm @ 90 psi is mandatory. Flow and pressure of lesser amounts will prevent operation of the machine hydraulic valving and subsequent operation of the machine functions if the operator is utilizing the air table during the grinding mode.

In order for the air table to function satisfactorily, the pressure of the air jet supply tubes must be set and regulated properly. To facilitate pressure settings, each supply tube is fitted with a pressure regulator and gage which is illustrated in Figure A3. As noted, the proper pressure settings are:

Supply Tube A - 30 psi

Supply Tube B - 30 psi

Supply Tube C - 30 psi

It is important that these pressures be maintained for proper operation of the air table.

Operation

To operate the 187C air-bearing worktable the steps below are to be followed:

1. Set the mode selector switch (located on the main operator control station) to "Manual".
2. Set the table bearing selector switch to "On". At this point the table bearing on indicator light should be lit.
3. If using the Vernac readout, set the positioning light selector switch to "On".

4. Position the worktable to the desired location by turning the traversing handwheel. A clockwise rotation moves the worktable to the right.
5. Set the table bearing selector switch to "Off" and proceed with the grinding.

ABRASIVE MACHINING

MACHINE SET UP

Part No. D8769051	Name - Shaft
D8769051	Shaft
D8765800	Crank

The Process Data Sheet for these operations list all the equipment, tooling, feed rates, etc. required to set up the machine.

The machine set up and grinding can best be accomplished by following the step by step set up procedure as outlined in this report and as specified in the manufacturer's manuals. This covers all the following steps:

A. Installing the grinding wheel.

B. Truing the wheel.

C. Soaking the wheel.

D. Mounting the crusher roll.

E. Crushing the grinding wheel.

F. Automatic crush cycle.

G. Grinding.

H. Hints and suggestions for crushing and grinding.

I. Air Bearing Table Setup.

NOTE: If machine is going to be idle for a period of time do not stop the grinding wheel until the oil has been spun out. This will prevent wheel from becoming out of balance. It is recommended that the wheel be run at grinding speed for at least 1/2 hour before stopping.

ABRASIVE MACHINING

TOOLING SET UP ON 187C TYPE MACHINE

This report illustrates the tooling set up for a 187C type machine. The "C" machine differs from the "B" by the addition of an air bearing table on the platen. (See operation of air table.) The workhead and tailstock are now mounted on the table instead of the platen. This eliminates the necessity of the workhead and tailstock being accurately positioned laterally relative to the wheel. By switching on the air bearing (control on left front of platen) and using the hand wheel on the left, it is possible to position the part, work-head, tailstock and locator as a unit relative to the grinding wheel.

For tooling set up refer to tool drawings.

Part No.	Name	Table Layout	Tool Layout
8769051	Shaft	80503264	80503109
8769051	Shaft	80503264	80503110
8765800	Crank	80503264	80503112

Tooling Set Up on 187C type machine.

1. Follow standard operating and general instruction.
2. Turn on table air bearing.
3. Position table.
4. Turn off air bearing.
5. Mount part locator on table per table layout.

6. Lay part on locator and position to the right far enough that when the tailstock center moves the part to the headstock center, the part is not off the locators.
7. Position headstock to part, allowing clearance between the end of center and part for part removal.
8. Clamp headstock.
9. Position tailstock such that when the quill is extended approximately 1-1/2" the part has been moved onto the headstock center and the part is now riding on centers and clears the locator.
10. Clamp the tailstock
11. Turn on air bearing table and position part relative to wheel for grinding.
12. Adjust vernac scale to zero or some even figure.
13. Spark out on part by rotating to contact highest point.
14. Retract wheelhead to neutral.
15. Turn coolant off.
16. Check part for lateral location.
17. If correction is required, turn on air bearing and move table to right or left as required using vernac scale for proper move.
18. Turn off air bearing.
19. Continue set up of machine as outlined.

OPERATIONAL SEQUENCE FOR CRUSH FORM ABRASIVE MACHINING
OF .357 + .001 - .001 TENSILES

TURN ON MASTER SWITCH

REFRIGERATION: Turn on pump - Check visually for coolant circulation.

Turn on Cooling

FILTER: Depress Master Start

Depress Filter Pump Start

Conveyor Drive on "Auto"

Precoat feeder on "OFF"

JET WHEEL CLEANER: Set on "Auto"

CONTROL PANEL: Depress both "Master Start" and

"Reset Emergency Return" buttons at the same time.

Depress "Manual"

Depress "Fast Wheel Start"

Depress "Workhead Start"

Allow wheel & workhead to warm up for approx. 1 hour.

WHEN READY TO GRIND: Depress "Workhead Stop"

Depress "Hand-Auto Reset"

Depress "Auto"

Set Coolant Switch at "Int."

Depress "Auto Cycle Start"

"Master Stop" will stop all functions in place

"Emergency Return" will return wheel head to neutral and then stop everything.

NOTE: Before shutting machine down for any length of time, one (1) hour or more, run wheel with coolant off for a minimum of one half (1/2) hours to allow coolant to spin from wheel. Failure to spin coolant from wheel will result in vibration and an out-of-balance condition.

ABRASIVE MACHINING

MACHINE SET UP

WARNING

This machine was designed for the grinding wheel to operate at a maximum of 1750 RPM or 11,000 SFPM. Do not mount any wheels that have not been tested and stamped to operate at this speed.

APPENDIX B

PROCESS DATA

ABRASIVE MACHINING

PROCESS DATA

Part No. D8765800 Name - Crank, 105mm M68 Oper. No. 1

ITEM	DESCRIPTION	
Machine	Bendix Model 187C - 60 H.P.	
Filtration	Delpark Filtermatic #8-9x36	
Refrigeration	Hansen 15 H.P. - Air Cooled	
Mist Collector	Smog Hog - 2400 C.F.M.	
Wheel Cleaner	Bendix Super Jet Wheel Cleaner	
Wheel Speeds	7500 SFPM - 1150 RPM	
Work Speed	270 RPM	
Crushing Rate	.008/Min.	
Infeed Rate	.108/Min. Fast - .054/Min. Slow	
Depth of Grind	.650 - .435 Fast - .215 Slow	
Coolant	Metgrind WV2	
Tailstock Pressure	30 PSI	
Jet Wheel Cleaner Press	6000 PSI	
Dwell Timer	10 Sec.	
Air Bearing Pressure	A Bearing	30 PSI
	B Bearing	30 PSI
	C Bearing	30 PSI

TOOLING	
Crusher Roll	Carbide
Grinding Wheel	Bendix Abrasive 24 x 6 x 12.050

Part No. D8765800 (Continued) Name - Crank Oper. No. 1

ITEM	DESCRIPTION
Grinding Wheel	Laminated Wheel -
	29A80N5V124 (4-3/4" Wide)
	29A60N5V124 (1-1/4" Wide)
	or Equivalent
Part Locator	See Tool Layout

ABRASIVE MACHINING

PROCESS DATA

Pt. No. - D8769051 | Name - Shaft, 175mm M113A1 & 8" M2A2 | Oper. No. 1

ITEM	DESCRIPTION
Machine	Bendix Model 187C - 60 H.P.
Filtration	Delpark Filtermatic #8-9x36
Refrigeration	Hansen 15 H.P. - Air Cooled
Mist Collector	Smog Hog - 2400 CFM
Wheel Cleaner	Bendix Super Jet Wheel Cleaner
Wheel Speeds	7500 SFPM - 1150 RPM
Work Speed	300 RPM
Crushing Rate	.008/Min.
Infeed Rate	.20/Min. Fast - .060/Min. Slow
Depth of Grind	.560 - .310 Fast - .250 Slow
Coolant	Metgrind WV2
Tailstock Pressure	30 PSI
Jet Wheel Cleaner Pressure	6000 PSI
Dwell Timer	10 Sec.
Air Bearing Pressure	A Bearing 30 PSI
	B Bearing 30 PSI
	C Bearing 30 PSI

Part No. D8769051 (Continued) | Name - Shaft | Oper. No. 2

ITEM	DESCRIPTION	
Air Bearing Pressure	A Bearing	30 PSI
	B Bearing	30 PSI
	C Bearing	30 PSI

TOOLING

Crusher Roll	Carbide
Grinding Wheel	Bendix Abrasive 24 x 3.5 x 12.050 #29A100N5V124 or Equivalent
Part Locator	See Tool Layout
Part Drive Dog	See Tool Layout
Tailstock Center	See Tool Layout

NOTE: Same Part Locator, Drive Dog and Tailstock Center used for Oper. #1 and #2.

PROCESS DATA

Part No. D8769370 Name- Bushing, 175mm M113A1 & 8" M2A2 Oper. No. 1

ITEM	DESCRIPTION
Machine...	Bendix Model 187-30 60 HP
Filtration...	Delpark Filtermatic #8-9 x 36
Refrigeration...	Hansen 10 H.P. Air Cooled
Mist Collector...	Smog Hog 2400 CFM
Wheel Cleaner...	Bendix High Velocity Jet
Machine Capacity...	30" Dia. x 9"
Wheel Size...	24" Dia x 7-1/2 W. x 12.050 I.D.
Wheel Spec. ...	29A60N5V124
Wheel Speed...	11,000 SFPM
Work Speed...	40 RPM
Crushing Rate...	.005/Min.
Infeed Rate...	.020 Fast to .006 Slow
Depth of Grind...	.540
Coolant...	Metgrind WV2

APPENDIX C

COST ANALYSIS

SECTION

ABRASIVE MACHINING
COST ANALYSIS

Part - Metallurgical Tensile Test Specimen

Description	Time Minutes	Set-Up Cost	*Cost per 100 Pieces
Mounting the Wheel	45	$15.00	$15.00
Mounting the Crush Roll	20	6.66	6.66
Dressing the Periphery	10	3.33	3.33
Crushing New Wheel	90	30.00	30.00
Set Up Machine Cycle	10	3.33	3.33
Machining Cycle	3	1.00	100.00
Part Handling	1	.333	33.33
Crusher Roll		600.00	600.00
		$659.66	$791.65

Average Grinding Time: 4 min. ea. piece

Total Cost per Piece Based on 100 Pieces: $7.92

*Cost Comparison Machining Only Previous Cost Ea. Piece	Abrasive Machining Present Method
1.1 Hrs. Ea. = $20.66	4 Min Ea. $1.33 ea.

Savings per piece: $19.33

*Cost Based on Labor Rates of $20/hr.

ABRASIVE MACHINING COST ANALYSIS

Part - Crank 105mm M68

Part No. D8765800

DESCRIPTION	Time Minutes	% Time	Set-Up Cost	Cost * Per 100 Pcs.
Mounting the Wheel	45.	19.7	15.00	15.00
Mounting the Crusher Roll	20.	8.7	6.66	6.66
Dressing the Periphery	7.	3.0	2.33	2.33
Crushing New Wheel	120.	52.5	40.00	40.00
Mounting & Indicating Tools	20.	8.7	6.66	6.66
Set-Up Machine Cycle	10.	4.3	3.33	3.33
Machining Cycle	7.	3.0	2.33	233.00
Part Handling	.33	.1	.02	2.00
Crusher Roll			790.00	790.00
Total	229.33	100.0	866.33	1098.98

Average Grinding Time ... 7 Min. ea. pc.

Cost per piece based on 100 pcs. ... $10.99

*Cost based on labor rate of $20/hr.

ABRASIVE MACHINING COST ANALYSIS

Part - Bushing 175mm M113 & 8" How. M2A2

Part No. D8769370

DESCRIPTION	Time Minutes	% Time	Set-Up Cost	Cost * Per 100 Pcs.
Mounting the wheel	45	17.5	15.00	15.00
Mounting the Crusher Roll	20	7.8	6.66	6.66
Dressing the Periphery	10	3.9	3.33	3.33
Crushing New Wheel	90	35.	30.00	30.00
Mounting & Indicating Tools	30	11.8	10.00	10.00
Set-Up Machine Cycle	10	3.9	3.33	3.33
Machining Cycle	40	15.6	13.32	1332.00
Part Handling	11	4.5	3.66	366.00
Crusher Roll			945.00	945.00
Total	256	100.0	1030.30	2711.32

Average grinding time ... 40 Min. ea. Pc.

Cost per piece based on 100 pcs. ... $27.11

*Cost based on labor rate of $20/hr.

ABRASIVE MACHINING COST ANALYSIS

Part - Shaft 175mm M113 & 8" How. M2A2

Part No. D8769051

DESCRIPTION	Time Minutes	%Time	Set-Up Cost	Cost * Per 100 Pcs.
Mounting the Wheel	45	21.	15.00	15.00
Mounting the Crusher Roll	20	9.3	6.66	6.66
Dressing the Periphery	10	4.6	3.33	3.33
Crushing New Wheel	90	42.	30.00	30.00
Mounting & Indicating Tools	20	9.3	6.66	6.66
Set-Up Machine Cycle	10	4.6	3.33	3.33
Machining Cycle	16	7.4	5.33	533.00
Part Handling	4	1.8	1.33	133.00
Crusher Roll			965.00	965.00
Total	215	100.0	1036.64	1695.98

Average Grinding Time ... 16 Min. ea. pc.

Cost per piece based on 100 pcs. ... $16.95

*Cost based on labor rate of $20/hr.

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